



Airborne fungi in Universiti Sains Malaysia: knowledge, density and diversity

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Abstract Airborne fungi are among common contaminants in indoor and outdoor environments, leading to poor indoor air quality (IAQ), and to some extent, implicate health risks to humans worldwide. In Malaysia, fungal contamination in institutional buildings is rarely documented although these places are frequently visited by many. This study was conducted to assess the density and diversity of airborne fungi in Universiti Sains Malaysia (USM) main campus, Penang. A total of 11 sampling sites were assessed. Fungi were collected by using Andersen Single Stage Impact Air Sampler N-6 and MEA plates. Two separate trials, namely Trial 1 and Trial 2, were

conducted in 2008 and 2019, respectively. The recovered fungi were identified up to the genus level—based morphological features. A survey involving 400 respondents among USM staff and students in relation to fungal contamination in indoor air environment was also conducted to evaluate the knowledge on indoor fungi among USM community. The densities of indoor air fungi in Trial 1 were higher; ranging from 81 to 1743 CFU/m³, exceeding the recommended level set by the Malaysia Industry Code of Practice (MCPIAQ) in some sampling sites, compared to that of in Trial 2 where the densities ranged from 229 to 699 CFU/m³. A total of 154 isolates and 230 isolates of airborne fungi were recovered in Trial 1 and Trial 2, respectively. In total, 11 fungal genera were identified in both trials, and three genera were predominant: *Aspergillus*, *Penicillium*, and *Cladosporium*. The survey also revealed that knowledge of IAQ among staff and students was limited and that they were unaware of fungal contamination and IAQ. A continuous and wide-spread awareness should be implemented at USM main campus for safer and healthier indoor air environments, particularly university students where productivity and efficiency are of the utmost importance.

Highlights

- The fungal densities of indoor air fungi in 2008 were higher than in 2019
- The number of fungal isolates recovered in 2019 is 1.5-fold more than that of in 2008
- The three most predominant fungal genera were *Aspergillus*, *Penicillium*, and *Cladosporium*
- Age differences had a significant impact on knowledge and awareness concerning fungal contamination and IAQ

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Introduction

In the present society, 90% of the people spend on average 22 h/day in indoor environments (Zomorodian et al.,

2016). However, the quality of indoor air can be 10 times worse than the outdoor environments (Kankaria et al., 2014). Among all the documented air pollutants, airborne microorganisms are one of the important factors affecting the indoor air quality (IAQ) of buildings and the occupants' well-being (Cincinelli & Martellini, 2017). Despite the unfavorable condition of atmospheric air that lack nutrients, the airborne microorganisms are still present throughout the environment (Pavan & Manjunath, 2014). These airborne microorganisms use the air circulation such as sneezing, coughing and breezes as transmission routes to reach suitable surfaces for colonization in aerosol form (Tringe et al., 2008).

Fungi are ubiquitous in nature and are commonly found in outdoor and indoor environments (Baxi et al., 2016). They are considered as the main air pollutants, detectable via the presence of visible mycelial growth and distinctive musty odor (Afanou et al., 2015; Priyamvada et al., 2017). Today, fungal infections in human are perceived as a difficult disease to manage as they can cause diseases in both healthy people and also individuals with serious illness (Köhler et al., 2015). Worldwide, fungal diseases can affect over a billion of individuals and cause more than 1.5 million deaths as the infections tend to be chronic, difficult to diagnose and hard to eradicate by antifungal drugs (Bongomin et al., 2017; Casadevall, 2018).

Fungi possess various sizes and shapes of spores, enabling the airborne fungi to disseminate in the air via ventilation from air conditioning systems, doors and windows, connecting the air in the enclosed buildings with outdoors (Shelton et al., 2002). *Cladosporium* sp., *Penicillium* sp., *Aspergillus* sp., *Alternaria* sp. and *Epicoccum* sp. are among the notable fungal allergens (Baxi et al., 2016; Shelton et al., 2002). Their presence reduces the indoor air quality (IAQ) of buildings and affect building occupant's well-being, causing health problems such as asthma, hypersensitivity and allergy (Baxi et al., 2016; Bennett & Klich, 2003; Cincinelli & Martellini, 2017). In more serious cases, fungal infection can cause death to immune-compromised individuals (Simon-Nobbe et al., 2008).

Studies conducted by the Environmental Protection Agency (EPA 2005) showed that indoor air pollution is among the top environment health risks causing different symptoms associated with sick building syndrome (SBS), a condition in which the building occupant's health is affected due to poor IAQ (Norhidayah et al., 2013). Several common SBS symptoms include headache, dizziness, eye, nose or throat irritation,

nausea, dry or itching skin, difficulty in concentration, hoarseness of voice, increased incidence of asthma attacks and decrease in work productivity (Ghaffarianhoseini et al., 2018; Joshi, 2008). Therefore, the Ministry of Human Resource Malaysia has introduced Malaysian Industry Code of Practice on Indoor Air Quality (MCPIAQ) in 2010 with the main purpose to set up minimum standards of the indoor air quality to ensure the health of both employees and occupants in the enclosed buildings (MCPIAQ, 2010).

Questionnaire surveys have been done previously in hospitals, houses, schools and workplace to assess the IAQ and symptoms of SDS (Reijula & Sundman-Digert, 2004; Frontczak et al., 2012; Ung-Lanki et al., 2017; Veysi et al., 2019). The studies have linked the association between occupants' satisfaction and health symptoms with IAQ. However, information on the knowledge of the occupants on airborne pollutants is scarce, hence limiting the awareness on the importance of healthy indoor environments. There are many IAQ studies focused on the emission sources of air pollutants, but the survey on occupants' health and satisfaction is often disregarded (Wu & Chou, 2018). A questionnaire survey is recommended to be carried out together with the indoor environmental measurements and building assessment for a more reliable IAQ assessment (Carrer & Wolkoff, 2018; Ung-Lanki et al. 2017).

Most of the IAQ studies in university buildings were carried out in temperate regions, and relatively few have been conducted in tropical regions. In Spain, for example, the lecture halls and classrooms of a university recorded 105 to 205 CFU/m³ of indoor fungi (Soto Pino et al., 2009). Meanwhile, a university in Poland recorded fungal concentrations ranging from 230 to 520 CFU/m³ and 90 to 520 CFU/m³ in the lecture halls and laboratory (Stryjowska-Sekulska et al., 2007). The presence of the airborne fungi in university is not limited to buildings involved in the present study; airborne fungi have been collected from several other university buildings such as libraries (Wu et al., 2020), cafés (Osimani et al., 2016), hospitals (Chaivisit et al., 2018) and sports hall (Oneţ et al., 2018).

The findings from IAQ studies in temperate regions such as the microbial counts and isolated species may not be applicable to tropical countries due to differences in temperature, seasons and relative humidity (Hussin et al., 2011). Thus, the present study was conducted to assess the density, diversity of indoor air fungi and to survey the knowledge and

awareness on IAQ among the community in Universiti Sains Malaysia (USM), Penang, Malaysia.

Materials and methods

Two separate trials were conducted in 2008 (Trial 1) and 2019 (Trial 2) at 11 arbitrarily selected sampling sites in USM main campus, Penang. These sites represented different types of buildings such as, lecture halls, hostels and laboratories that are frequently visited by students and lecturers (Fig. 1).

Indoor and outdoor air sampling

Air samples were collected from each sampling site in both trials. Modifications on the experimental design were made for Trial 2 in which multiple sampling replicates were done as opposed to Trial 1. Each location was sampled for three times (one month apart for each sampling) in Trial 2. The air sampling was conducted between 8 a.m. and 2 p.m. using the single-stage E6 sampler (Microbial Sampler Model 120,101, Environmental Monitoring Systems, Charleston, SC, USA). Air samples were impacted on malt extract agar (MEA) at 16.45 L/min for 3 to 5 min at the height of breathing zone of 1.5 m above floor level (Rahman et al., 2012). A total of two MEA plates were used for each sampling site. The plates were then transferred to the laboratory and incubated at room temperature (23–25 °C) for 6 to 10 days. Outdoor air was collected outside

the main buildings of the sampling sites (Fig. 1), similarly as described for indoor air sampling. All MEA plates were incubated at room temperature (23–25 °C) for 7 days (Marshall et al., 1998). Temperature and relative humidity (RH) of the sampling locations were also recorded.

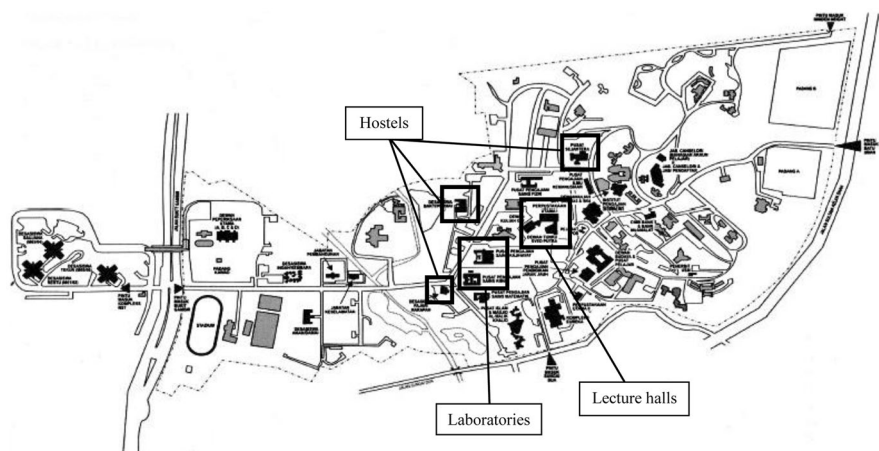
Fungal density

The density of collected airborne fungi was determined by counting the observable fungal colonies on the incubated MEA plates and converted to colony-forming unit per m³ (CFU/m³) (Sharma et al., 2011). Observable fungal colonies on the MEA plates were then isolated by transferring the colonies onto potato dextrose agar (PDA) for fungal identification.

Identification of fungi

To observe the fungal morphology, all isolated fungi were incubated at room temperature (23–25 °C) for 7 days onto water agar (WA), PDA and MEA. The identification involved observing the macroscopic (colony appearances and growth diameter) and microscopic characters (conidiogenous cells, spore shape and size). Fungi were identified to the genus level using the characteristics described by various references: *Aspergillus* (Raper & Fennell, 1965; Samson et al., 2014), *Penicillium* (Raper & Thom, 1949; Visagie et al., 2014), *Cladosporium* (Bensch et al., 2012; Ellis, 1971), *Curvularia* (Baron, 1984; Ellis, 1971), *Fusarium* (Hafizi et al., 2013; Leslie &

Fig. 1 Buildings composed of 11 sampling sites involved in Trial 1 and 2 at Universiti Sains Malaysia (USM) Campus, Penang, Malaysia



Summerell, 2006), *Rhizopus* (Samson et al., 2010; Zheng et al., 2007), *Nigrospora* (Ellis, 1971; Wang et al., 2017), *Pestalotiopsis* (Maharachchikumbura et al., 2011), *Trichoderma* (Rifai, 1969; Tan, 2013) and *Neurospora* (Harris et al., 1975; Nygren et al., 2011).

Questionnaire and data collection

The survey was aimed at understanding the fundamental knowledge and awareness of respondents on indoor air fungi and IAQ. The survey inventory built for this study comprised four parts: demographic questions; knowledge about fungus, daily practices and personal hygiene of individuals and symptoms encountered at workplace, lecture halls or at home. The survey questions on demographic, knowledge, practice and symptoms were modified from Frontczak et al. (2012), Reijula and Sundman-Digert (2004) and Ung-Lanki et al. (2017). A self-administered questionnaire was arbitrarily distributed to 400 respondents in Trial 2, in which a convenience sampling was adopted for recruitment. A cover letter elucidating the objective of the questionnaire was given together during the survey. The questionnaire took approximately 5 min to complete. Respondents were informed beforehand that confidentiality was assured, and their participation was based on voluntary basis. The sampling frame included students and staff who were at the 11 sampling sites at the time between 9 a.m. and 5 p.m. from 11 to 28 February 2019.

Data and statistical analyses

Data from Trial 2 was used to assess the species accumulation curve using EstimateS 9.1 software (Colwell, 2013). The species accumulation curve describes the number of new species obtained at each new sampling sites and the sampling effort sufficiency. Correlation analysis (SPSS v.24, Chicago, IL) was also carried out on Trial 2 to assess the relationship between fungal density with RH and temperature. Data from the survey were verified for normality using the Shapiro–Wilk test. Responses between age groups were compared and analysed using Pearson's chi-square test (SPSS v.24, Chicago, IL). Both descriptive and inferential statistics were employed for data analysis. The comparison of the symptoms factors between the different age groups was proposed in this study as presented by

Table 1 Colony forming unit, relative humidity and temperature recorded at 11 sampling sites in Trial 1 and 2

Building	Laboratory				Hostel				Lecture Hall													
	Laboratory 113	Botany laboratory	Marine laboratory	Physical Chemistry laboratory	Bakti Permai Hostel	Cahaya Gemilang Hostel	Fajar Harapan Hostel	Lecture hall T	Lecture hall U	Lecture hall N	Lecture hall G											
Trial	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	2									
Colony forming unit (CFU/m ³)	182	403	1439	338	587	330	729	588	709	699	1581	616	790	466	1743	393	81	541	182	229	101	354
Relative humidity (%)	59	52	72	45	76	67	76	70	89	67	93	62	79	65	74	55	76	63	84	65	79	52
Temperature (°C)	24	23	22	26	23	25	24	28	23	30	26	29	23	27	24	24	24	26	26	22	23	27

Nakayama et al. (2019) where the analysis showed that younger generations (age < 30) result in higher risk in suffering from SBS despite of sex.

Results

Fungal density, relative humidity and temperature

In Trial 1, three sampling sites had recorded > 1000 CFU/m³: Lecture Hall T (1743 CFU/m³), Cahaya Gemilang Hostel (1581 CFU/m³) and Botany Laboratory (1439 CFU/m³). The lowest reading in Trial 1 was recorded in Lecture Hall U (81 CFU/m³) (Table 1). The RH readings for Trial 1 ranged from 59 to 93%, and the temperature ranged 22 to 26 °C. In contrast, no CFU > 1000 CFU/m³ was recorded in Trial 2 (Table 1). The highest reading was recorded in Bakti Permai Hostel with 699 CFU/m³ and Lecture Hall N showed the lowest with 229 CFU/m³ (Table 1). For Trial 2, the recorded temperature was higher, and RH was lower than Trial 1. The highest recorded temperature and RH were 29 °C and 70%, respectively (Table 1). On average, hostel buildings recorded the highest CFU/m³ with 1027 CFU/m³, followed by laboratories (734 CFU/m³) and lecture halls (527 CFU/m³) in Trial 1. The pattern was similar in Trial 2: hostel buildings (594 CFU/m³),

laboratories (415 CFU/m³) and lecture halls (379 CFU/m³) (Table 1). However, there was no significant correlations between fungal density and temperature in both trials ($p_{\text{indoor}}=0.184$; $p_{\text{outdoor}}=0.724$) and between fungal density and RH ($p_{\text{indoor}}=0.058$; $p_{\text{outdoor}}=0.143$).

Indoor fungi

In total, 154 and 230 fungal colonies were isolated in Trial 1 and Trial 2, respectively. Observation on the morphological characters resulted in seven and 10 identified fungal genera in each trial (Fig. 2). The most recovered fungal genera in both trials were *Aspergillus*, *Penicillium* and *Cladosporium*. Several other genera were also isolated from both trials. However, some were only recovered either in Trial 1 or in Trial 2. For example, *Chrysosporium* was only isolated in Trial 1, whereas *Trichoderma*, *Neurospora*, *Nigrospora* and *Pestalotiopsis* were only isolated in Trial 2 (Fig. 2).

Outdoor air sampling

The fungal genera recovered were similar with those of indoor air samples. The most predominant genera were *Aspergillus*, *Penicillium* and *Cladosporium*. Similarly, *Chrysosporium* was only observed in Trial 1, whereas *Trichoderma*, *Neurospora*, *Pestalotiopsis*

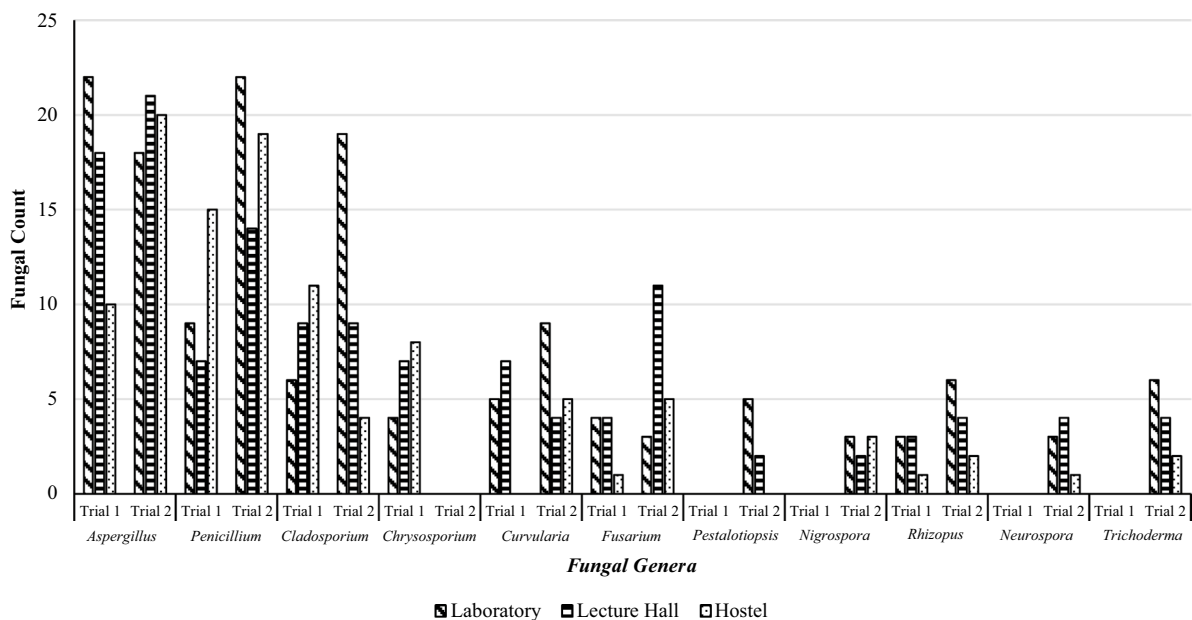
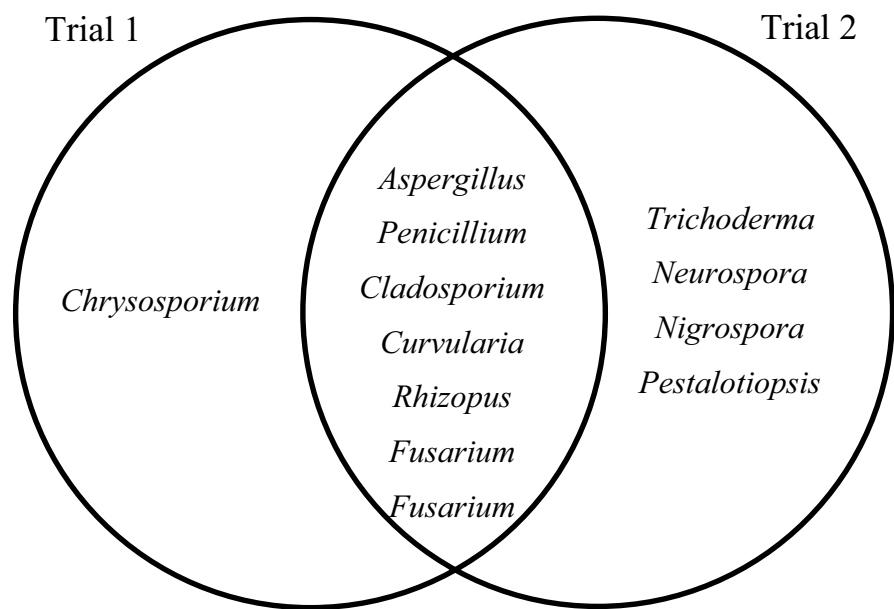


Fig. 2 Identified genera of indoor air fungi isolated from different building types in Trial 1 and 2

Fig. 3 Comparison of fungal genera isolated from the outdoor air in Trial 1 and Trial 2



and *Nigrospora* were only recovered in Trial 2 (Fig. 3).

Species richness

In general, each fungal genus represented the species. Figure 4 shows the accumulation curve of species richness in the present study. The number of fungal

species increased as the number of indoor air samples was added, indicating that different fungal species are of potential to be isolated with more air samples collected. However, the species accumulation curve for the outdoor air reached asymptote toward the end of the sampling (air sampling was conducted three times, once a month), indicating that most of the

Fig. 4 Species accumulation curve of fungal species richness from indoor and outdoor air, based on Trial 2

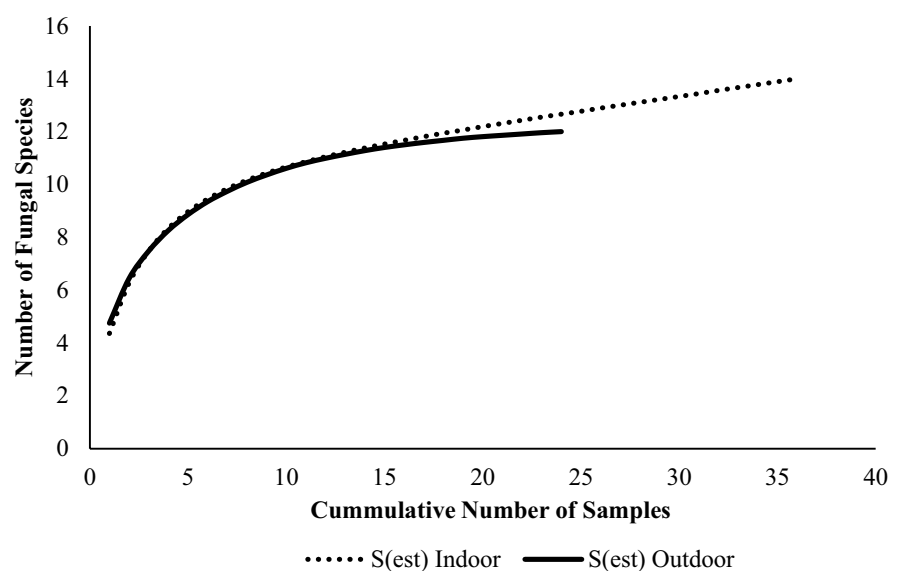
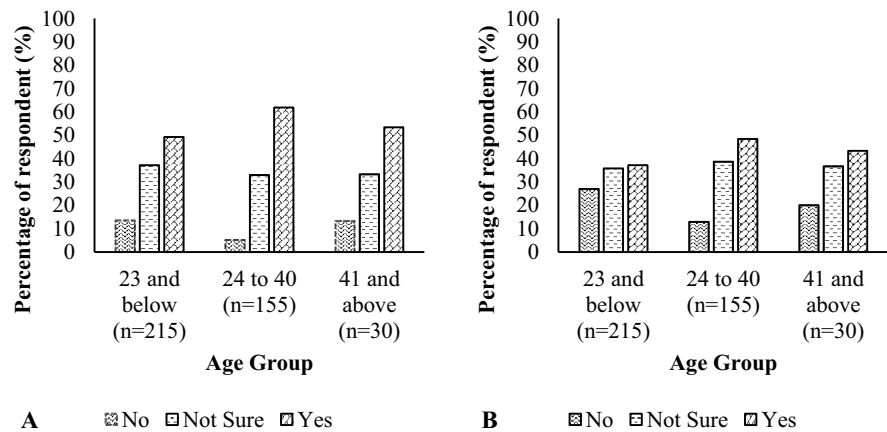


Fig. 5 Respondent questions that were significantly different among age groups. **A** Are fungi harmful to humans? **B** Are fungi one of the main contaminants in indoor air?



fungal species available in the outdoor air in the present study were successfully sampled (Fig. 4).

Knowledge and awareness on indoor air fungi and IAQ

The respondents were aged from 23 and below to above 41 years old. The largest group of respondents was age 23 and below (n=215), followed by age 24 to 40 (n=155) and age 41 and above (n=30). Most of the respondents showed no significant difference

on the general knowledge of fungi. However, the awareness on fungi as air contaminants ($p=0.049$) and their effect on human's health ($p=0.022$) was significantly different among the age groups (Fig. 5). All age groups of respondents showed no significant difference on daily practices and personal hygiene.

Table 2 shows the most common work-related symptoms reported by respondents. They experienced the same symptoms such as drowsiness or unusual tiredness, concentration difficulties, headache or nausea, runny or stuffy nose and itchy skin

Table 2 Comparison of health symptoms reported between age groups

Health symptoms	Age groups ^a								
	23 and below n = 215(53.75)			24 to 40 n = 155(38.75)			41 and above n = 30(7.50)		
	N (%)	S (%)	EW (%)	N (%)	S (%)	EW (%)	N (%)	S (%)	EW (%)
Stuffy nose/runny nose	25(6.3)	130(32.5)	40(10.0)	24(6.0)	85(21.3)	30(7.5)	6(1.5)	17(4.3)	5(1.3)
Dry or sore throat/hoarseness	60(15.0)	139(34.8)	13(3.3)	44(11.0)	101(25.3)	8(2.0)	9(2.3)	20(5.0)	1(0.3)
Cough/nocturnal cough	60(15.0)	140(35.0)	12(3.0)	51(12.8)	99(24.8)	5(1.2)	8(2.0)	22(5.5)	0(0.0)
Shortness of breath/wheezing	125(31.3)	83(20.8)	6(1.5)	100(25.0)	52(13.0)	3(0.8)	19(4.8)	10(2.5)	1(0.3)
Itchy eyes/watery eyes	81(20.3)	112(28.0)	17(4.3)	63(15.8)	79(19.8)	12(3.0)	14(3.5)	12(3.0)	4(0.8)
Rash/itchy skin/redness	58(14.5)	111(27.8)	37(9.3)	57(14.3)	67(16.8)	23(5.8)	14(3.5)	15(3.8)	1(0.3)
Sleep problems/drowsiness /unusual tiredness	27(6.8)	98(24.5)	62(15.5)	26(6.5)	76(19.0)	40(10.0)	4(0.8)	21(5.3)	5(1.3)
Headache/nausea	32(8.0)	137(34.3)	38(9.5)	27(6.8)	96(24.0)	26(6.5)	3(0.8)	24(6.0)	3(0.8)
Concentration difficulties ^b	22(5.5)	126(31.5)	53(13.3)	29(7.3)	87(21.8)	27(6.8)	12(3.0)	17(4.3)	0(0.0)
Depression ^b	107(26.8)	83(20.8)	21(5.3)	80(20.0)	66(16.5)	5(1.3)	19(4.8)	11(2.8)	0(0.0)
Muscle pain/joint pain/swelling in joints/backache	87(21.8)	94(23.5)	31(7.8)	58(14.5)	77(19.3)	12(3.0)	14(3.5)	13(3.3)	3(0.8)

^aThe results are expressed: *n* number of participants, *N* never, *S* sometimes, *EW* every week

^bResults are significant at $p < 0.05$

on a daily basis. Results from Pearson's chi-square test showed a significant difference between different age group, with regard to concentration difficulties ($p=0.000$) and depression ($p=0.045$). Other health symptoms were also reported by respondents, but no significant difference was observed among the age groups (Table 2).

Discussion

The present study demonstrated the fungal contamination status in USM buildings in 2008 and 2019. Overall, the CFU readings in all sampling sites decreased after a decade. The environmental condition in Trial 2 was much dryer than Trial 1, due to the lower RH and higher temperature readings recorded. This dryness condition potentially reduces the fungal dispersal and fungal availability in the air (Cáliz et al., 2018). The growth of biological contaminants relies greatly on the temperature and relative humidity (Rasli et al., 2019). However, temperature affects the fungal sporulation more than other weather inputs (Carlile et al., 2001). It is widely known that the world is currently facing climate change where the averaged surface temperature increases between 1.4 and 5.8 °C from the period of 1990 to 2100 (Feidas et al., 2004; IPCC, 2001; Walther et al., 2002). Since climate warming can affect the biosphere (Dighton & White, 2017), fungi can also be affected in their abiotic environment and biotic resource pools.

Even though no significant correlation was observed in the present study, the association between temperature and relative humidity with indoor fungi was reported elsewhere: Damialis et al. (2015) observed the reduction in fungal concentration with the increased air temperature recorded over two decades in Greece (temp.: 21–30 °C); Kalyoncu (2010) observed the highest fungal count and fungal species on sampling days with high temperature and low RH in a 2-year study in Turkey (temp.: 6–29 °C; RH: 44–69%), relative humidity-indoor fungal concentration was positively correlated in Singapore (Rajasekar & Subramanian, 2011), temperature-carpet fungal concentration was negatively correlated in an elementary schools in the USA (Ramachandran et al., 2005), and Abbasi and Samaei (2019) observed higher airborne fungal growth at 25 °C compared to that of 37 °C in Iran. Other environmental or seasonal

aspects that were not observed in the present study but were reported to have effect on fungal density were wind speed, precipitation and rainfall (Di Giulio et al., 2010; Newhouse & Levetin, 2004; Njokuocha et al., 2019; Okten et al., 2005; Pakpour et al., 2015). Additional years of sampling with appropriate analysis are, therefore, suggested to properly delineate the fungal concentration-weather input relationships in the present study.

MCPIAQ, 2010 has set the total fungal counts to be lower than 1000 CFU/m³ as safe for occupants. Rahman et al. (2012) previously revealed that the clinic at the USM campus recorded extremely high indoor air fungal concentrations, reaching up to 22,474 CFU/m³ due to an incident of pipe leakage. A similar pipe leakage incidence causing an upsurge concentration on airborne fungi was also reported at a tertiary-care hospital in the USA (Curtis et al. 2005). In this study, three sampling sites in Trial 1 exceeded the safety limit. The buildings were Botany Laboratory (1439 CFU/m³), Cahaya Gemilang Hostel (1581 CFU/m³) and Lecture Hall T (1743 CFU/m³). After a decade, however, these buildings had total fungal counts of less than < 1000 CFU/m³ and hence were in accordance with the outlined safety regulations. In Malaysia, several studies have previously recorded high indoor fungal concentration in various buildings. For example, Er et al. (2015) recorded 806 CFU/m³ of indoor fungi in one of the higher educational buildings in southern Malaysia, 810 CFU/m³ in heritage buildings and mosques (Prihatmanti & Bahaiddin, 2014; Rasli et al., 2019) and two children day care centres with > 1000 CFU/m³ (Khamal et al., 2019). The reading almost reached the safety limit set by MCPIAQ, 2010, and high RH (90%) was stated as the main factor.

Three fungal genera: *Aspergillus*, *Penicillium* and *Cladosporium* were the most prevalent in both trials. The present work adds to the considerable body of evidence that these fungi are common genera in indoor air samples. The prevalence of these fungal genera indoor has also been reported in various countries such as Nigeria (Uzochukwu & Nkpouto, 2013), India (Sharma et al., 2011), Iran (Ziaee et al., 2018), Poland (Ejdys, 2007) and the USA (Shelton et al., 2002). They are commonly referred to as fungal allergens and associated to many respiratory diseases, including asthma (Kim et al., 2018). *Aspergillus* spp. is notoriously known as the causal agent for numerous allergic reactions including rhinitis, broncho

pulmonary mycoses and hypersensitivity pneumonitis (Eng et al., 2016; Sugui et al., 2015). Similarly, *Cladosporium* is also found abundantly in indoor and outdoor environments (Uzochukwu & Nkpouto, 2013; Ziaee et al., 2018). The spores are dispersed by wind, and some are known to be the causal agents of allergic diseases (Levetin et al., 2016). *Penicillium* is also a common airborne allergenic fungal genus, along with *Cladosporium* and *Aspergillus*. Some species can even grow under conditions with limited water availability, and exposure to *Penicillium* could elevate a risk factor for asthma (Osborne et al., 2019).

The analysis of species richness based on Trial 2 in the present study showed that more fungal species were isolated from indoor buildings compared to the outdoor air. The results support the notion that indoor fungal genera are more diverse, and the total CFU is higher compared to that outdoor (Pavan & Manjunath, 2014). Durugbo et al. (2013) also reported that the concentrations and types of fungal spores isolated indoor were higher compared to that in outdoor environments. Indoor fungi presumably have a better opportunity for wider dispersal due to the presence of human mobility. In contrast, the dispersal of outdoor fungi is limited by natural mechanisms only such as splash or wind (Amend et al., 2010). The composition of indoor air fungi also can be shaped largely by local indoor environments such as construction materials, circulation system, and building function (Amend et al., 2010; Tran et al., 2020).

The surveys indicated that age differences had a significant impact on the awareness on indoor air fungi and their effect on human health. As such, respondents below 23 years old were less aware of fungi and IAQ compared to those who were above 41 years old. Adding to this, SBS symptoms were more profound among respondents in the age group of 23 years old and below (Table 2). Zainal et al. (2019) conducted a study in enclosed offices and found that younger respondents tend to suffer more SBS symptoms compared to older respondents. Previously, Vilčeková et al. (2017) have revealed that awareness on IAQ in universities and schools was low, and the occupants were unaware that IAQ has an impact on their daily productivity and health. Studies in a Brazilian University by Jurado et al. (2014) and schools in the USA by Simons et al. (2010) found that the health of the students was affected by poor IAQ which resulted in greater absenteeism in class. Therefore, creating an awareness of IAQ among the

younger generation (23 years and below) is crucial since ignorance and poor knowledge of IAQ can lead to a higher risk of health effect. For future studies, it would be worthwhile to demonstrate the association between USM students' attendance with their health condition affected by poor IAQ.

Meanwhile, the indoor questionnaire on the prevalent symptoms reported by Rahman et al. (2012) and Reijula and Sundman-Digert (2004) showed that the occupants suffered from fatigue, runny or stuffy nose, dizziness and headache and were also showed in the present study. Other types of building with poor IAQ were also leading to SBS symptoms among occupants. For example, Kielb et al. (2015) reported that teachers in the USA were experiencing sinus problems and headache due to poor IAQ in classrooms. In Mauritius, headache, fatigue and loss of concentration were experienced by workers in office buildings with high concentrations of fungal spores (Bholah & Subratty, 2002). There was also a significant difference between concentration difficulties and depression among the age groups. Respondents younger than 23 years old encountered a higher chance of having concentration difficulties and depression compared to the older respondents. This fits well with the previous findings of Kraus and Nováková (2019) and Wyon (2005) where poor IAQ can influence the concentration and daily productivity of the occupants. The conditions are usually projected where occupants stay too long in enclosed buildings which further lead to a decrease in occupants' productivity.

Inhalation of fungal spores could have an impact on the health of occupants such as hypersensitivity and chronic fatigue where the spores of the fungal can easily penetrate the lung (Sorenson, 1999). A study on the association between the IAQ and depression was done in Turkey where the result reported that poor IAQ influences the physical and mental health of a person that could trigger depressive symptoms (Acikgoz et al., 2013). Kim et al. (2020) reported depressive symptoms increase significantly when exposed to severe air pollution. In the USA, exposure to indoor emissions of fine particulate matter and increased ambient concentrations was also found to cause major depressive disorder (Taylor, 2020). Therefore, IAQ needs to be taken into account as a vital public health problem and awareness about the outcome of poor IAQ on the well-being of the public needs to be increased by using questionnaire surveys.

Conclusion

The findings showed that the overall level of fungal concentrations was below 1000 CFU/m³ after a decade, of which complied with the level recommended by the MCPIAQ, 2010. Conversely, the fungal genera were more diverse after a decade, increased from seven to 10 different genera, suggesting the indoor environments become more favorable for numerous fungal growths. This study can be used as a reference in improving the indoor air quality in indoor environments of universities as well as other institutions for the benefits and well-being of the occupants. The application of DNA-based assessment and continuous monitoring on fungal infestation on facilities would be necessary as preventive measures. Occupants ought to have safer and healthier indoor air environments, particularly university students where productivity and efficiency are of the utmost importance.

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Data availability Available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare no competing interests.

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